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EVALUATION OF SHOVEL/LOADER OPERATION AT HIGHVALE MINE IN ALBERTA

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EVALUATION OF SHOVEL/LOADER OPERATION AT HIGHVALE MINE IN ALBERTA

by

V. Srajer*

ABSTRACT

Site specific and also common operating practices applicable to shovel and loader operation at the Highvale mine in Alberta are summarized in this report. The production data of shovel and loader were also collected and are evaluated here.

The summary of mine data are evaluated and tabled to determine average cycle times, bucket fill factors, time to fill different trucks employed at the mine, their total productive and delay times.

The bucket fill factors and correction factors for depth of cut and the swing angle were calculated. The shovel availability and utilization data were evaluated and are presented in graphs, showing operating and delay hours for the fourteen months period.

Several parameters needed in development of the shovel and loader computer simulation model were identified.

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ÉVALUATION DU RENDEMENT EFFECTIF DU RÉSEAU DE CHARGEUSES-PELLETEUSES À LA MINE HIGHVALE EN ALBERTA

par

V. Srajer*

RÉSUMÉ

Dans ce rapport, l'auteur présente un résumé ayant trait aux particularités du terrain et aux méthodes d'exploitation habituelles des chargeuses-pelleteuses à la mine Highvale en Alberta. Des données concernant le rendement des pelles et des chargeuses ont également été recueillies et font l'objet d'une évaluation.

Les données en provenance de la mine sont évaluées et présentées sous forme de tableaux de façon à ce qu'il soit possible de déterminer la durée moyenne des cycles d'opération, les facteurs déterminant le remplissage du godet, la période de temps qu'exige le remplissage des différents camions utilisés à la mine et les périodes de production et de retards totales des camions.

On a également fait le calcul des facteurs de correction concernant la profondeur de la coupe et l'angle de rotation de la pelle excavatrice. Les données relatives à la disponibilité et à l'utilisation de la pelle font l'objet d'une évaluation et sont présentées sous forme de tableaux indiquant les heures de fonctionnement et les retards pour une période d'une durée de quatorze mois.

Plusieurs paramètres nécessaires pour la mise au point d'un modèle de chargeuse-pelleteuse automatisé devant être utilisé dans des programmes de simulation ont été identifiés.

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INTRODUCTION

This report is a part of the studies undertaken by the Calgary Coal Research Laboratory in evaluating mining equipment and mine operating practices at the Highvale mine in Alberta. The study is a joint project of CANMET, National Research Council of Canada and TransAlta Utilities in Calgary, and is aimed at development of comprehensive computer simulation model for surface mining operation.

In this report, the loading practices, shovel and loader performances are evaluated and their production is analyzed. The shovel and loader parameters are also summarized and identified for inclusion in the shovel/loader model data base.

The study of operating practices and equipment used at Highvale mine is only presented here. The time study described is a summary of the events of shovel operation at Highvale mine.

The time study of Highvale mine equipment were undertaken during the period of June 1983 and February 1985. The utilization and availability of the equipment was calculated using mine historical data for the period of April 1982 to April 1983.

DESCRIPTION OF OPERATION

During the survey at the Highvale mine, four shovels and one loader were operational. The shovels observed were BE-190B electric, loader observed was identified as Dart 600 F.E.L.

Table 1 summarizes the loading equipment, its location by pit and I.D. number of the equipment.

Table 1 - Loading equipment summary

No.	Loading equipment		Location
	Type	Number	
1	BE-190B	1320	Pit 02S
2	BE-190B	1353	Pit 02S
3	BE-190B	1337	Pit 03
4	BE-190B	1247	Pit 03
5	Dart 600C	8056	Pit 03

The Highvale mine in Alberta is a multipit-multiseam operation. A total of five coal seams are mined at any time in three different pits: Pit 02, Pit 03, Pit 04. The Pit 04 was not fully operational during the time of the study and therefore no time study of shovel operation was undertaken there. The study of trucks operation from Pit 04 was completed previously and is included in another reports (1,2,3).

The shovels at the Highvale mine are used to remove coal in five seams. The coal zone is made up of six identifiable seams which are numbered from top to bottom and separated by shale partings. The No. 5 seam is made up of thin discontinuous coal stringers and is the only seam not recovered. Seams No. 1 and 2 are 100% blasted and the top of each seam is ripped, seams No. 3, 4 and 6 are ripped only. The shovel are also used to remove the partings between seams 4 and 6. The waste material is side-casted directly on spoil. The loader was observed loading both coal and partings. Generally, it is used at any pit as needed. Most of the time the loader is assigned to remove partings by loading it into the rear-dump trucks.

The coal at the Highvale mine is hauled by bottom-dump haulers to Sundance or Keephills power generating stations. The partings are usually dumped directly at the spoil side of the pit, or hauled to be spread on the haulage roads or ramps in the pit. The shovels and the loaders were observed several times loading partings into the coal haulers that then dumped the load on the haulage road to improve the road surface. The dozers and packers were used to spread the partings on the road. The loading operation is carried out seven days a week, 24 hours a day, in a two 12 hours shift.

The shovel was observed in two shovel positioning methods - during the frontal approach and during the parallel approach. Most of the time, shovels would be in the parallel approach that provided straight forward, fast shovel move-ups. The shovel was positioned in the desired width of cut and simply dug straight forward. The trucks were usually placed at one side only, positioned to face the shovel operation. This arrangement minimized delays caused in the truck spotting. The trucks were also able to move out quickly just by driving out from their loading position. The truck queuing line was usually formed behind the loading truck, minimizing the delay in truck positioning.

A shorter shovel swing was also observed by using this method of positioning, because the swing angle of the shovel was up to 90° most of the

time. The loading was from shovel positioned at the same level as truck or elevated above the truck.

The frontal approach was observed only to remove isolated coal pockets, at the end of the pit or near access ramps. The shovel moves them in semicircle, working directly towards the face. During this operation, it is very important to maintain clear, level floor as much as the machine will allow. The operator will then back out of the cut and reposition himself to the right of the cut. The trucks are then able to be positioned closer to the shovel at either side by backing towards the shovel. This minimizes the truck spotting and almost eliminate delay caused by moving away from the loading position.

The loader was observed working in Pit 03 only during the study. There are several factors having effect on loader performance, such as:

a. operating load capacity
b. bucket size
c. material weights.

The normal all day operating capacity is determined by the size of the load in the bucket that can be lifted by the loader hydraulics in any bucket position and carry this load on a hard, moderately smooth and level surface having a minimum speed of 6 km/h.

The bucket size is based on the operating load capacity of the loader and the size selection depends on the weight of material and operating conditions. Only the SAE rated capacity of the bucket adjusted by its fill factor is used for production calculation.

The weight of the material is determined by using loose material weight applied to heaped bucket capacities. The loader cycle time is based on road condition and the material excavated. At the Highvale mine, the cycle times varied considerably and were three times as long for excavation of hard material. The condition of the pit bottom affected rolling resistance and with higher values for rolling resistance the cycle time increased, sometimes up to 250%.

The operating practices presently employed at the Highvale mine, are well suit and to presently used truck and shovel system. It was observed, that the loading equipment did not cause delays in production at all. On one occasion only the trucks were found in the queuing position at the shovel. Most of the time shovels were waiting for the trucks to arrive. During this

waiting period, the shovel operator did clean up around the shovel or did some stockpiling of the coal. Only once, the shovel was observed to move to advanced position during truck loading, causing delay. The shovels were capable of loading or digging regardless of weather or any other production delay in the pit.

EVALUATION OF PERFORMANCE FACTORS

SHOVEL PERFORMANCE

Common practices observed at the Highvale mine can be summarized as follows:

1. Consolidated material was drilled and blasted, or ripped prior to excavating.
2. The shovel operated on a level and flat digging floor.
3. New seam digging commenced always downhill permitting therefore higher digging thrust forces because the gravity added to the machine's resistance to movement away from the digging face.
4. The digging face was always lower than the boom point sheave.
5. The toe of the bank was below the rear of the point sheave.
6. The crawlers were perpendicular to the face to minimize possible damage from sliding material at the face and also to facilitate positioning manoeuvres.
7. The shovel frequently move close to the face maximizing the effectiveness of the crowd and hoist forces.
8. An efficient dipper path was co-ordinated through the bank, starting at the toe and filling in a single pass.
9. The dipper was filled in two or three dipper lengths because of the uniform penetration of the face.
10. The shovel operator was trained to minimize stalling of the motors while digging in order to optimize motor life.
11. The top of the seam was ripped to ease hoisting through the lower portion.
12. The boulders or frost caps were removed by digging underneath and then lifted out with the dipper.
13. The shovel operator prepared the face while waiting for trucks by raking the face with the ripper.

14. The swing angle was kept as low as possible to minimize cycle time.
15. The loading was always over the rear of the truck to avoid any spillage near the truck driver cabin.
16. The dipper was open close to the truck box load to minimize the impact from the discharge.
17. The shovel operator was apparently instructed to load fines first into truck to provide cushion for subsequent coarse materials.
18. No personnel were allowed to come within shovel operating radius without prior notification of the shovel operator.

A typical shovel-truck laoding plan with truck drive-by as employed at the Highvale mine is shown in Fig. 1.

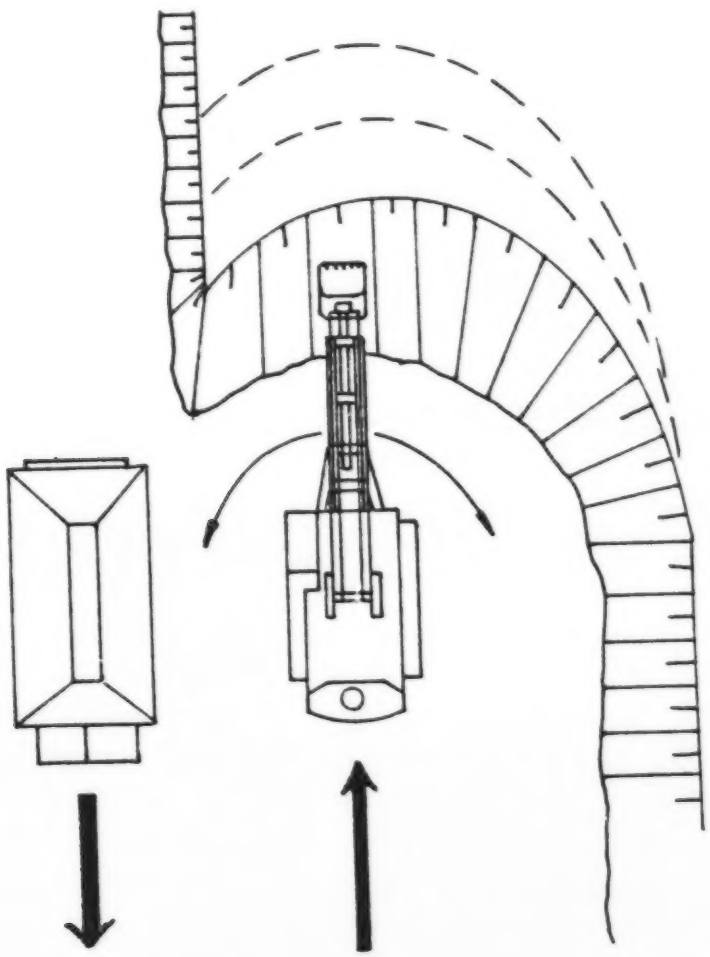


Fig. 1 - A typical shovel-truck loading plan

Generally, the angle of swing of the shovel was held to less than 90° to minimize the loading time. Also, by increasing the depth of the cut, the frequency of machine moves is reduced because of the wider digging face area. In this case, the trailing cable does not cross a truck driving path but the tires are more exposed to dipper spillage. The shovel can readily set oversize material aside without interferring with truck operation. Trucks are not required to back up into the loading position. The production is somewhat lower than for the double loading pattern.

A combined effect of three factors determines shovel production:

1. Time of the cycle
2. Dipper fill factor
3. Shovel utilization.

The full cycle can be divided into four segments: load, swing, dump and return.

A large amount of oversize material will adversely affect shovel production. Also, poorly blasted material effects shovel production; not only the loading time, but the swing and dump time as well. The long loading times generally reflect inability to get a good load with one pass of the dipper.

The dumping times are effected by poorly blasted, frozen or oversized material as well. The study by Norwest Engineering (4) summarizes the effect of oversize material on the loading and dumping times. (Fig. 2, 3).

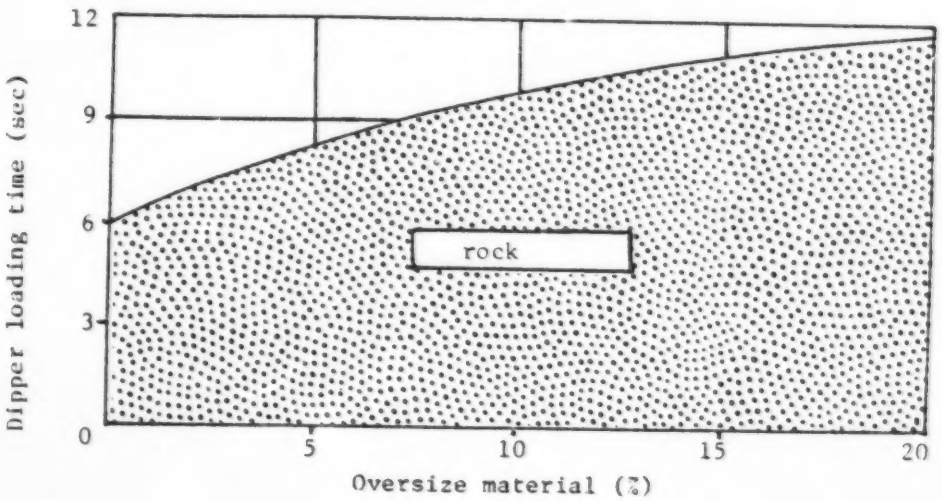


Fig. 2 - Oversize material vs dipper loading time graph

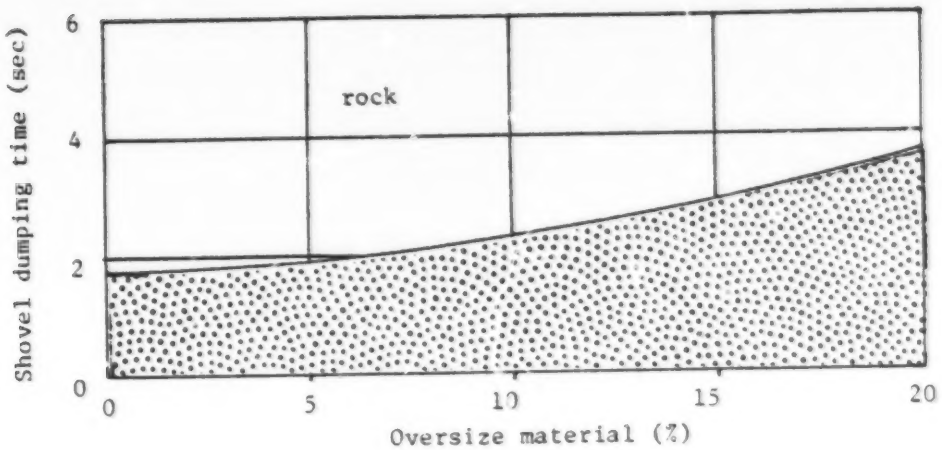


Fig. 3 - Oversize material vs shovel dumping time graph

Other factors having significant effect on the dipper fill factor are height of the digging face and the angle of swing. The size of the average load is considerably less at the thin seam, requiring an extra dipper pass and thus increasing loading times. The following Figures 4 and 5 show the curves illustrating swing and return times plotted against the angle of swing (4).

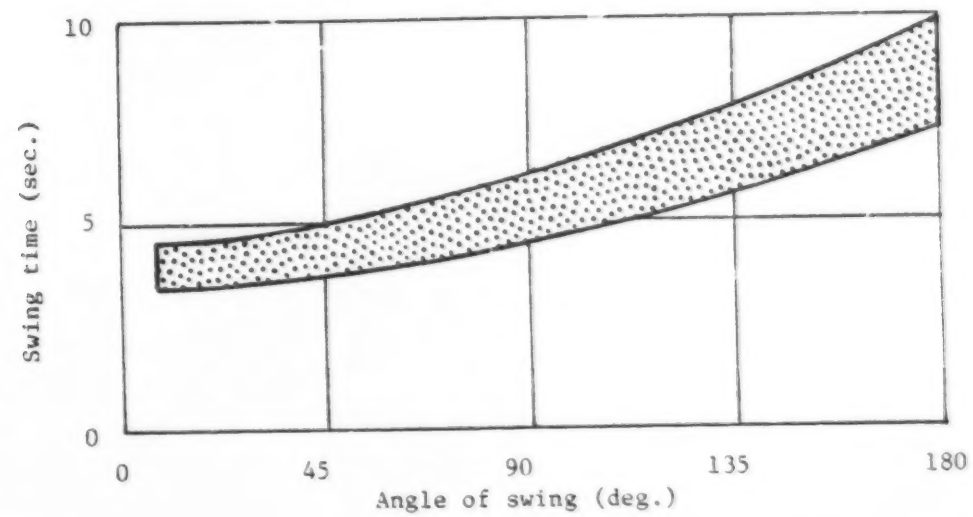


Fig. 4 - Angle of swing/swing time graph

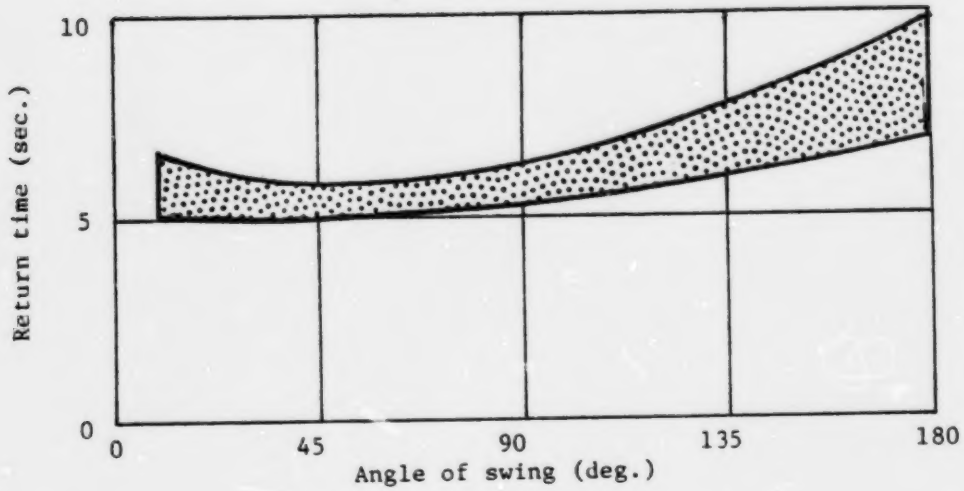


Fig. 5 - Angle of swing/return time graph

The problem of larger swing angle could be reduced to some extent by organizing the working area to permit spotting of the hauling units at the most practical location.

LOADER PERFORMANCE

The loader is a competitive excavator, able to load and transport material. It competes with shovels and dozers and over short transport distances, with scrapers and trucks. The loader is quite fast, mobile, and versatile, it is used in a number of mine applications.

The loader digging ability is lower than shovel when digging in consolidated digging faces, therefore it finds many of its applications in softer formations. At the Highvale mine, Dart 600C front-end loader is used at various pits to load coal, soft partings or to stockpile material. The primary applications are the following:

1. Loading and transporting partings
2. Loading coal at face
3. Loading coal at stockpile
4. Loading topsoil.

The loaders were observed to load and transport partings in Pit 03 at a distance of up to 150 metres and travelling on grades up to 12%. The loaders were also used for final pit clean-ups, removal of boulders and frozen material, road maintenance, etc.

The general characteristics and operating practices of the loaders at the Highvale mine are described as:

1. Mobility and high speed (up to 40 kmh).
2. Dump height from 3 to 7 m.
3. Maximum reach up to 3 m.
4. Tipping loads of 60% to 80% of machine weight.
5. Good gradeability
6. Good turning radius because of the articulated frame is hinged at mid point so that rear wheels tracks front wheels.
7. High ground pressures compared to the truck units.
8. Single operator with moderate skill required.
9. Moderate reliability.
10. Maintenance performed in the shop.
11. Low service life of up to 15000 hours.
12. Ability to handle large pieces with its wide bucket.
13. Ability to dig material selectively with a minimum of waste.
14. Good blending capabilities at working face.
15. No auxiliary equipment required.
16. Dumping action is generally easy on trucks but wide bucket can result in spillage.
17. Prior site preparation (ripping or blasting) is required when digging consolidated material.
18. Considerable manoeuvring space is required.
19. Reduced performance and bad traction on wet surfaces, soft ground, clay surfaces.
20. High tire wear on abrasive floor.
21. Reduced stability in load and carry position.
22. Poor visibility rearward while manoeuvring.

There are several factors determining loader performance, such as relationships between the bucket size and operating weight, horsepower and breakout force. The following graphs illustrate the relationship described (Figs. 6,7,8).

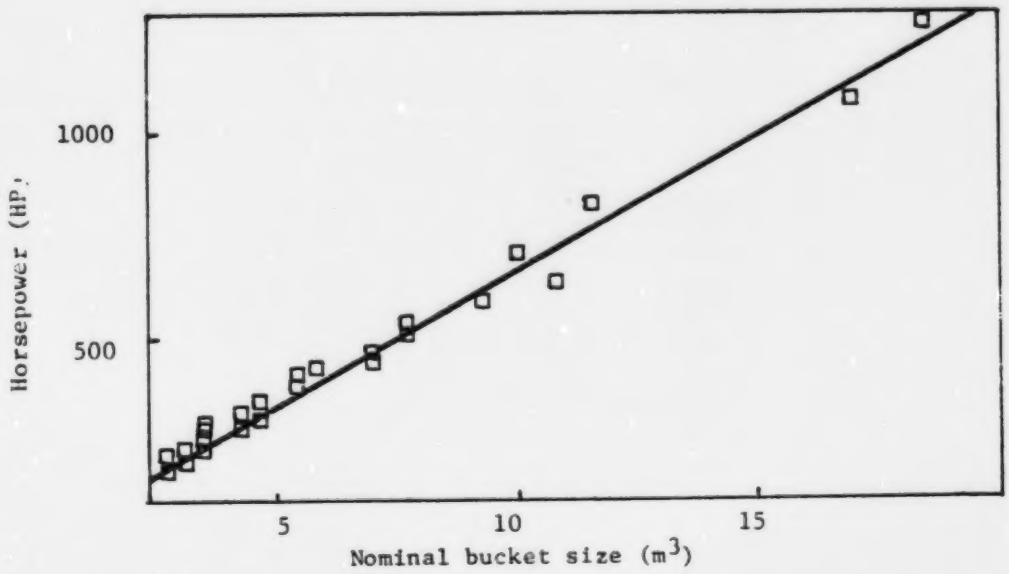


Fig. 6 - Operating weight/bucket size graph

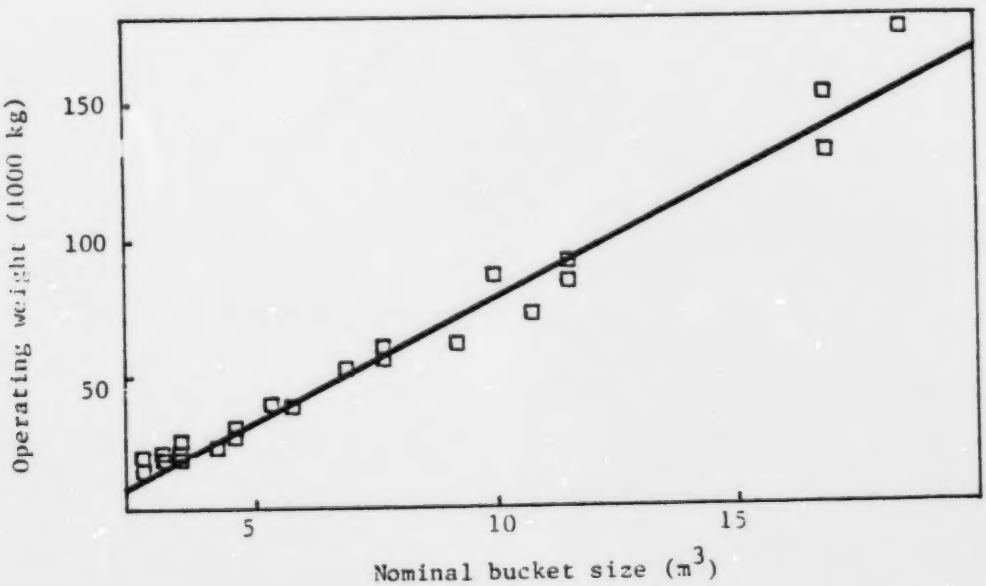


Fig. 7 - Horsepower/bucket size graph

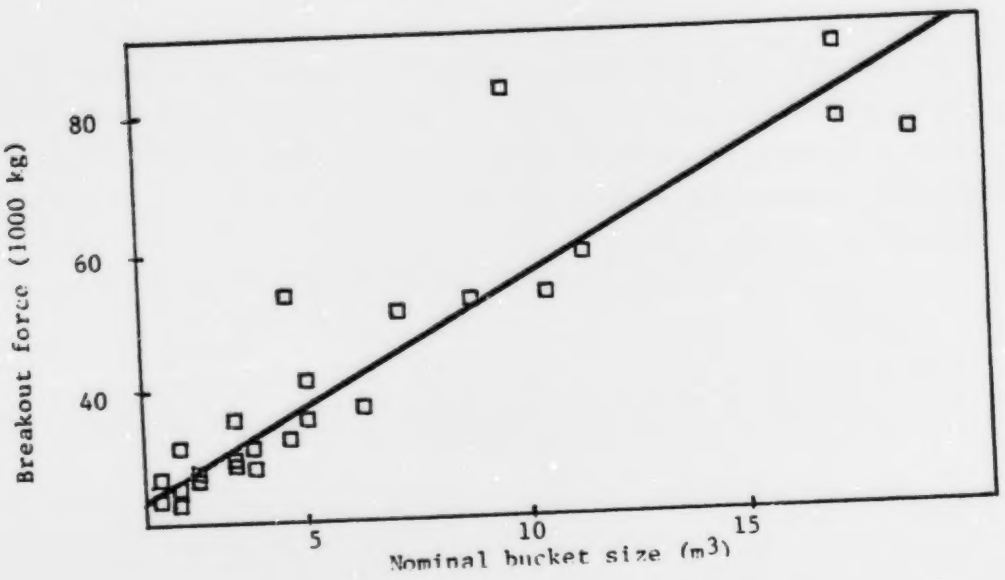


Fig. 8 - Breakout force/bucket size graph

It is be concluded that the linear relationship exis etween operating weight, horsepower and breakout force as compared to the size of the bucket.

The relationship is calculated using the following equations:

1. For operating weight/bucket size:

$$Y = 9.28X - 15.28 \quad \ldots\ldots\ldots\

The more rugged machines are proportionally heavier, have more inertia and require more power with increased fuel consumption. The available power and structural strength restrict maximum total breakout force.

The term "rimpull" at loaders is used to describe the tractive force between the loader's tires and the ground. The maximum rimpull is a function of the engine's power, transmission characteristics, and the gear ratios of the drive train. The usable rimpull can be limited by the traction between the wheels and the ground.

The loader at Highvale mine was generally employed in two operations, such as:

- direct loading
- load-and-carry.

Figure 9 illustrates Dart loader cleaning top at the coal in pit.

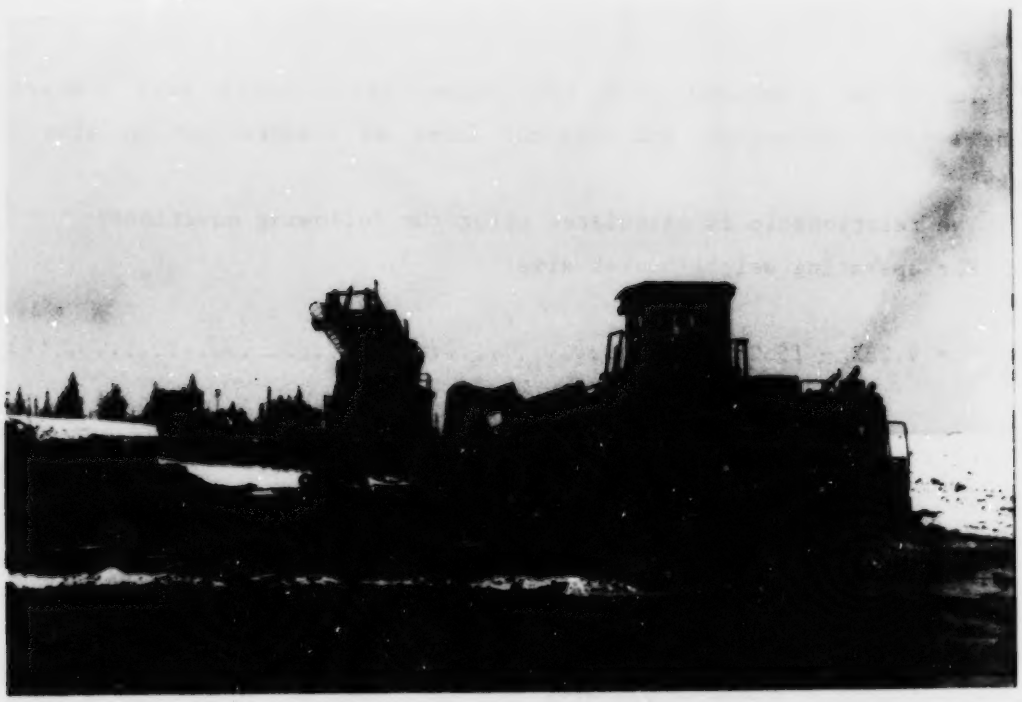


Fig. 9 - Dart loader

The following items must be closely observed when loader performance factors are evaluated:

1. Material characteristics, swell and bank or loose weight
2. Bucket size
3. Payload
4. Digging conditions
5. Loading arrangements and delays
6. Travelling characteristics such as grade, rolling resistance, distance and maximum speed
7. Job efficiency
8. Machine availability
9. Operating schedule
10. Machine cost and projected life
11. Maintenance and operating cost
12. Machine safety
13. Operators training
14. Power consumption and cost.

PRODUCTION ANALYSIS

In this chapter, the shovel and loader availabilities and utilizations are investigated. The mechanical availability and equipment utilization was calculated using the following equations:

$$MA = A/(A+B) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

where MA - mechanical availability
A - total operating hours
B - down time only.

$$UT = (A+C)/D \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

where UT - equipment utilization
C - delay times
D - total hours (include down time, delay time and idle time).

The data on file are used to produce graphs illustrating loader and shovel operating hours and delay hours for the evaluated period (April 1982-April 1983). Five variables are illustrated:

1. Total operating hours
2. Down time
3. Delay time
4. Idle time
5. Total hours.

The graphs are for each shovel and loader separately. The data on file are from listing HGV-20 to HGV-24 stored on tape "Highvale mine" and evaluated using "MPDA" library package on the HP-45 microcomputer.

Using file data, mechanical availability and equipment utilization was calculated and presented in summary forms.

SHOVEL AVAILABILITY AND UTILIZATION

The listing of data on file is in Appendix to this report as follows:

Appendix 1: HGV-21 BE-190B Shovel No. 1247 (Fig. 10)
Appendix 2: HGV-22 BE-190B Shovel NO. 1320 (Fig. 11)
Appendix 3: HGV-23 BE-190B Shovel No. 1337 (Fig. 12)
Appendix 4: HGV-24 BE-190B Shovel No. 1353 (Fig. 13).

Each month is represented by the number, ranging from 1 to 13 for the period of April 1982 to April 1983. The graphs were evalauted and the following was observed.

Shovel No. 1247 (Fig. 10)

This shovel was operating in Pit 03. It experienced major down time delay during August 1982 and in February 1983 that reduced the operating hours significantly. The delay times was generally lower except in January 1983. The idle time drops after August 1982 and is at minimum level after November 1982. The delay in August was because of repair of the swing shaft and pinion requiring 456 hours of mechanical work. With a reduction in down time later on, the idle time was reduced accordingly.

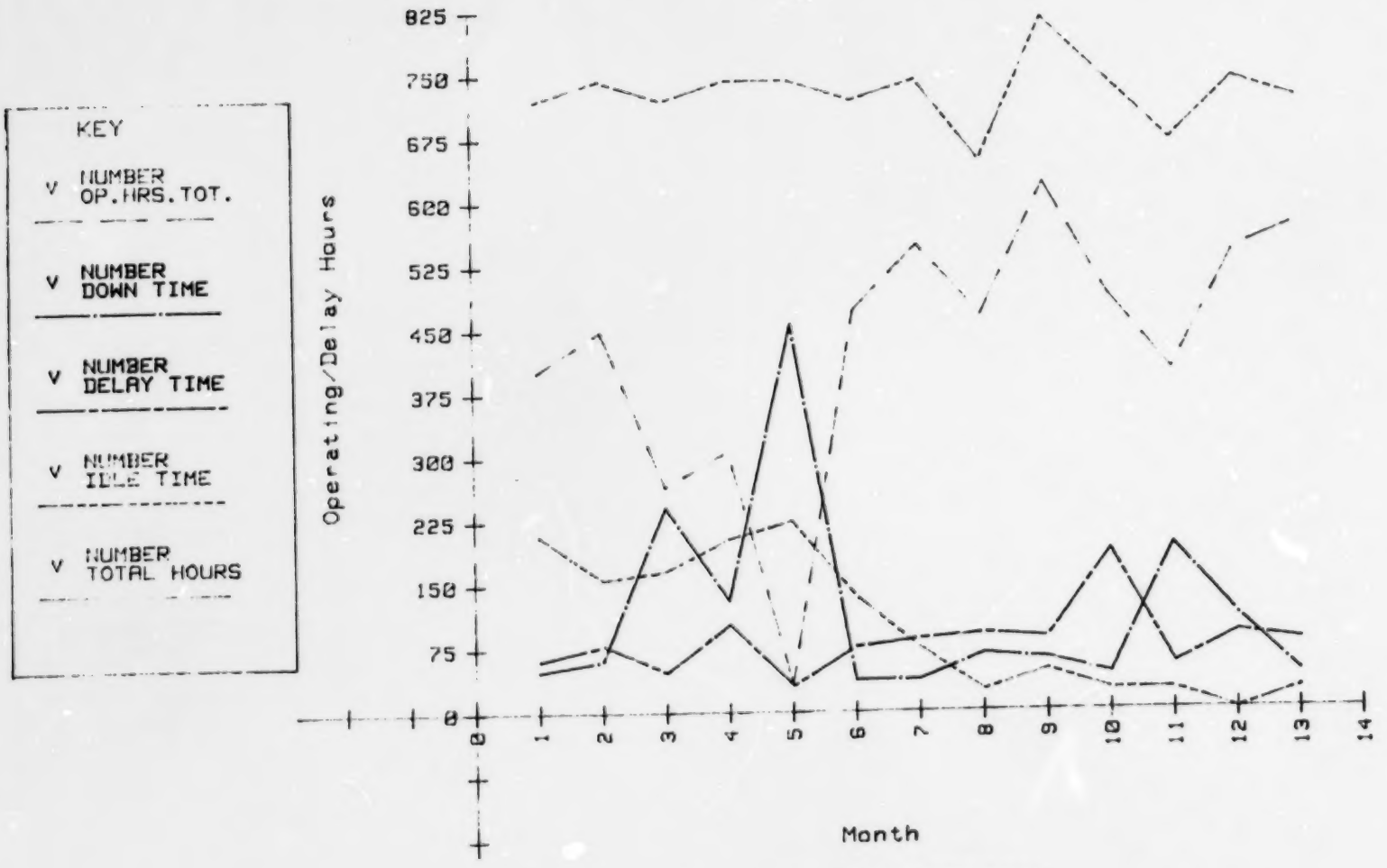


Fig. 10 - SHOVEL AVAILABILITY AND UTILIZATION
HIGHVALE MINE: B-E 190 B (No.1247)

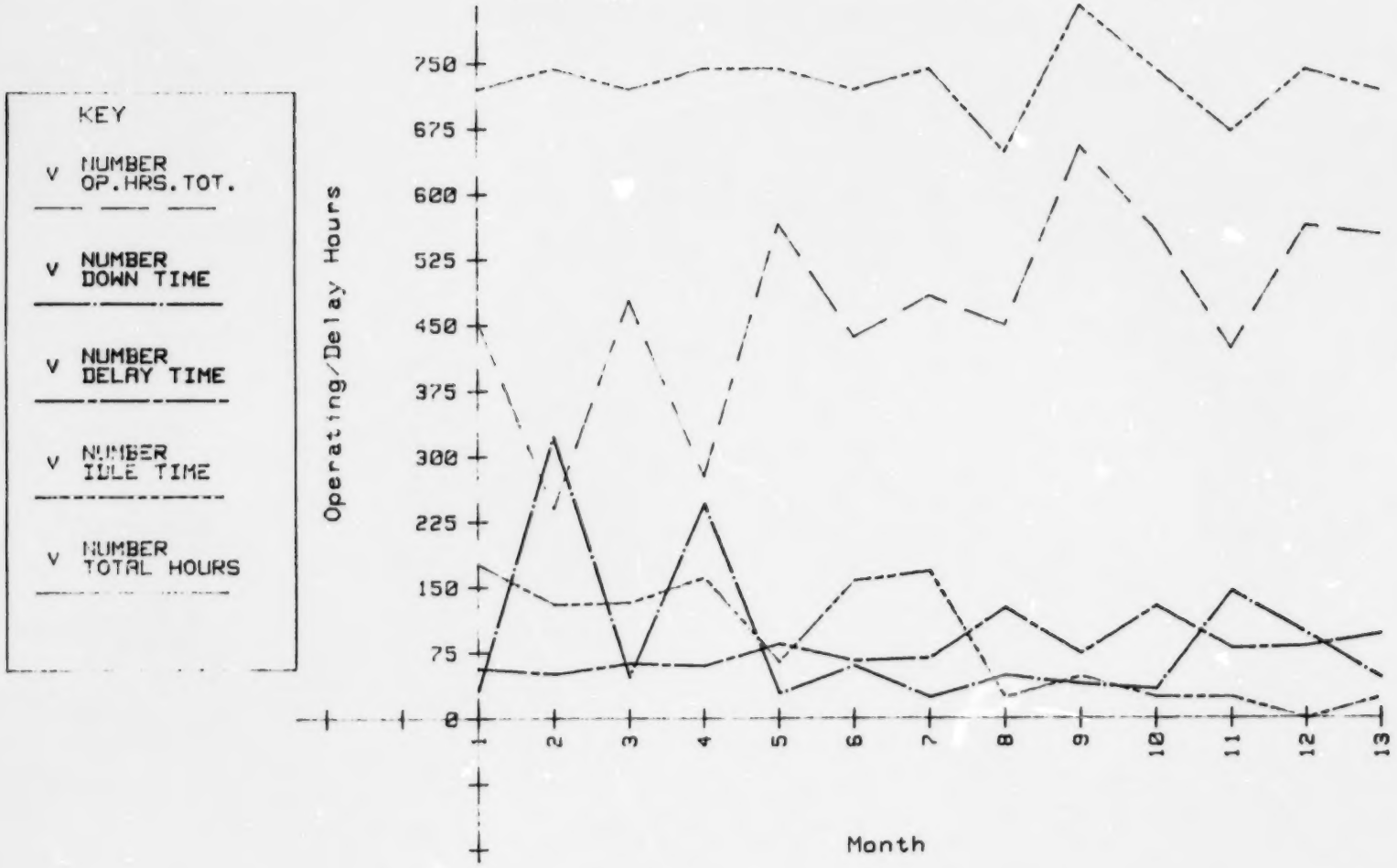


Fig. 11-SHOVEL AVAILABILITY AND UTILIZATION
HIGHVALE MINE:B-E 190 B (No.1320).

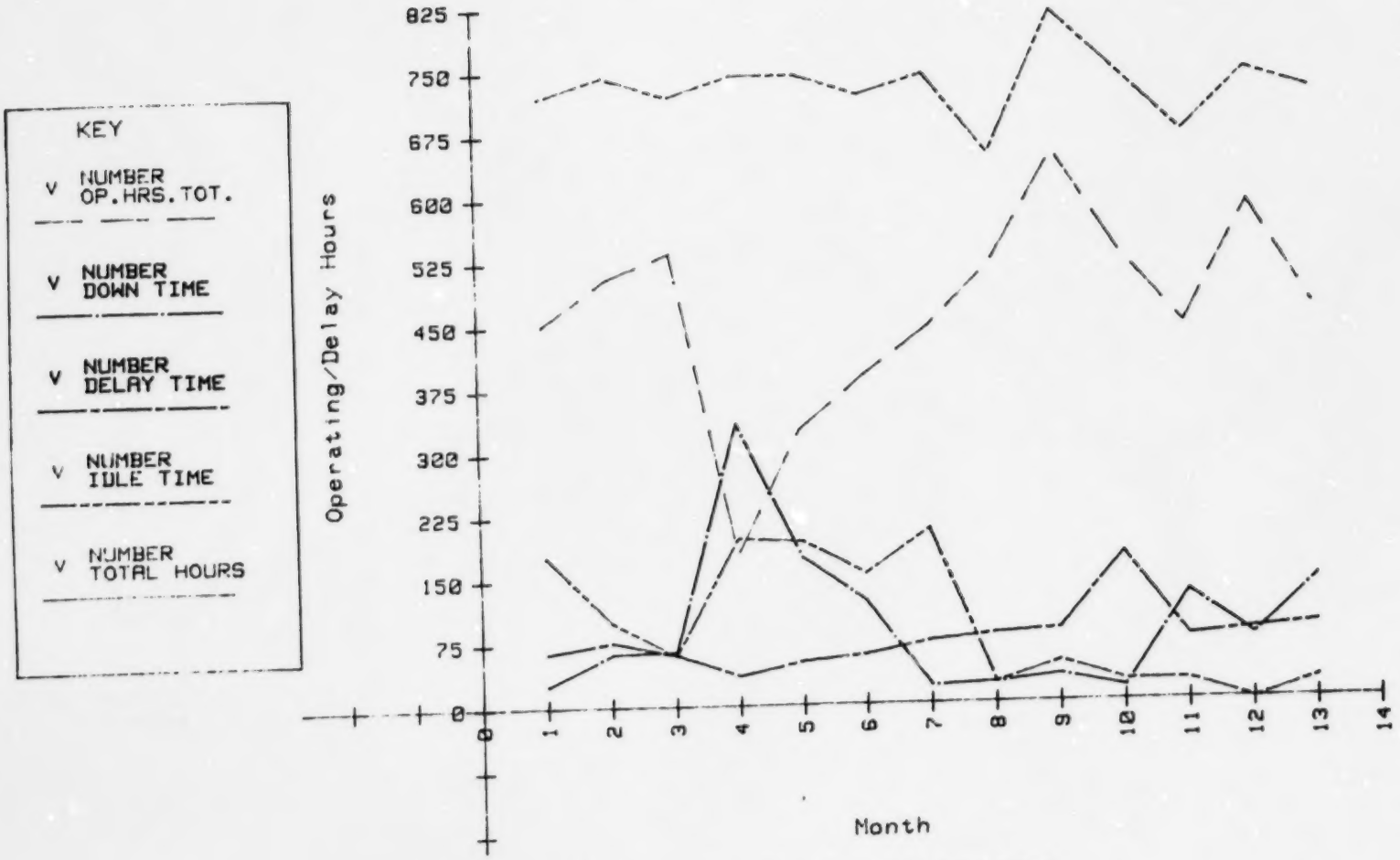
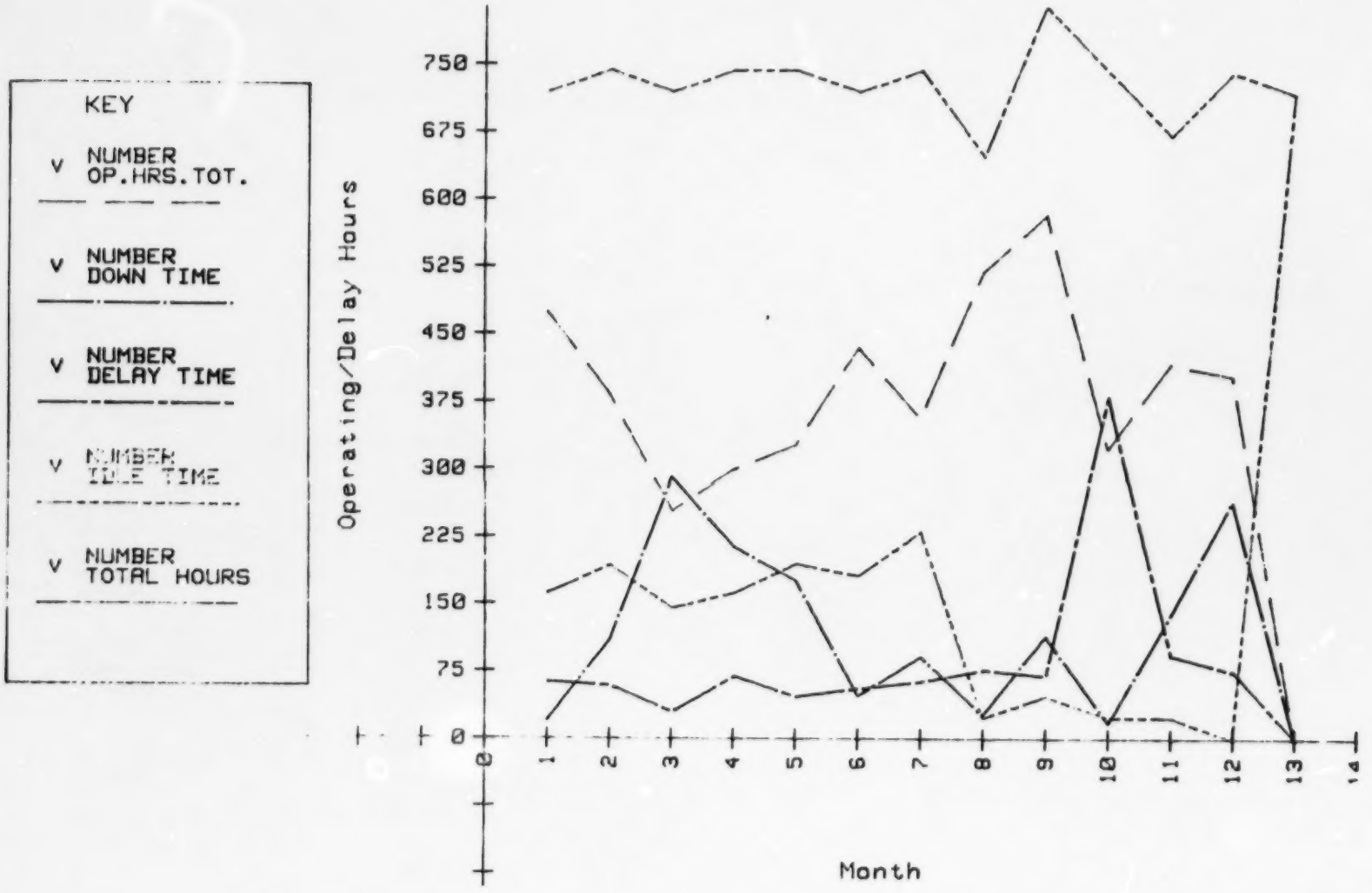


Fig. 12-SHOVEL AVAILABILITY AND UTILIZATION
HIGHVALE MINE:B-E 190 B (No.1337)



13 - SHOVEL AVAILABILITY AND UTILIZATION
HIGHVALE MINE: B-E 190 B (No. 1353)

Shovel No. 1320 (Fig. 11)

This shovel was operating in Pit 02S. No mechanical problem was recorded as reason for down time of the shovel in May and July 1982, except for cleaning and repairing. The delay and idle times remain fairly level and low during the survey period.

Shovel No. 1337 (Fig. 12)

This shovel operated in Pit 03. The repair of power propel in July 1982 increased the down time and accordingly reduced the operating hours. Approximately 45% of operating hours available in July 1982 were used for this repair.

Shovel No. 1353 (Fig. 13)

This shovel operated in Pit 02S. In June 1982, the hoist gear was repaired, using 40% of allocated operating hours. In March 1983, a total of the 36% of allocated operational hours were needed to rebuild shovel stick. The idle time decreased and stabilized in November 1982.

Generally, the delays were due to the major repair of the equipment. These repairs were planned and scheduled for summer months when demand for coal production is lower because the Highvale mine supplies coal for the power generating station. All demand for electrical power increased during winter seasons, increasing also the demand for coal.

The mechanical availability and equipment utilization for each individual shovel was calculated and is summarized.

Table 2 - Mechanical availability and shovel utilization

Shovel No.	Hours				MA	UT
	A	B	C	D		
1247	5566	1531	1073	9480	0.78	0.70
1320	6139	1171	1037	9480	0.84	0.76
1337	6023	1223	1003	9480	0.83	0.74
1353	4770	1516	1083	9480	0.76	0.62
TOTAL	22498	5441	4196	37920	0.81	0.70

From the presented table is apparent that the shovel's mechanical availability is quite uniform and averages 0.81.

The equipment utilization of the shovels was rescorded to be 0.70, being as low as 0.62 for shovel No. 1353 located in Pit 02S and as high as 0.76 for shovel No. 1320 located also in Pit 02S.

The operating hours and non-productive hours as listed in Appendix A1 to A4 do not add to total due to allocation of shovels to duties specified as "others". The "other" duties include non-productive work such as pulling its own cable, etc.

LOADER AVAILABILITY AND UTILIZATION

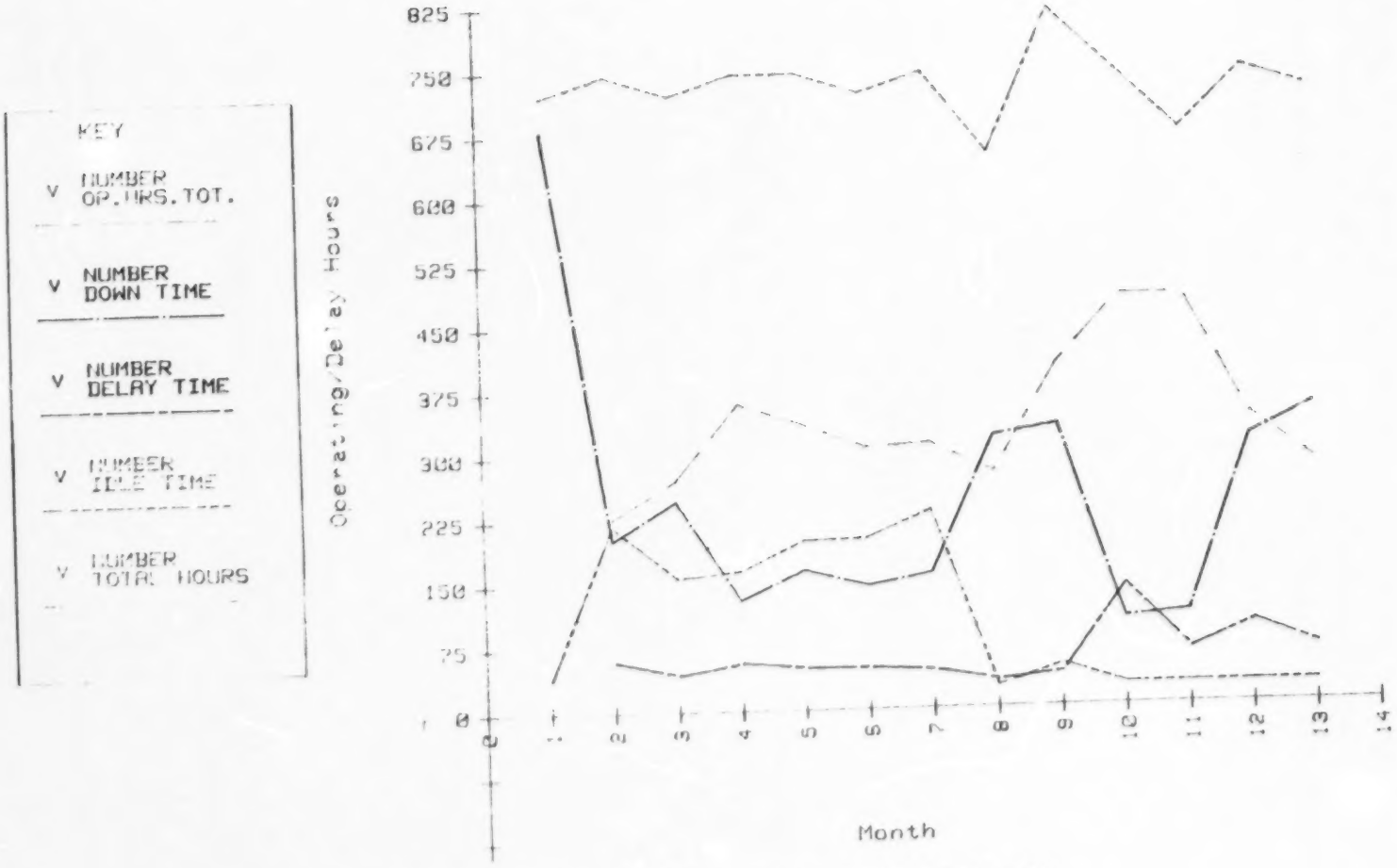
The listing of data on file to calculate the loader availability and utilization is in Appendix A5. There is only one loader - Dart 600C - used at the mine site.

The data fromthe listing were used to produce a graph (Fig. 14). In the graph the months under observation (April 1982 to April 1983) are related to the total operating hours, down time, delay time, idle time and total hours.

The major engine repair used 95% of the total operating hours in April 1982. The repair of front axle and differential in December 1982 caused 40% of total operating hours to be lost. Later on, in March and April 1983, new transmission was installed and the loader was scheduled for complete overhaul, therefore being non-operational for about 45% of the time. The mechanical availability and utilization is shown in Table 3.

Table 3 - Mechanical availability and loader utilization

Loader No.	Hours				MA	UT
	A	B	C	D		
8056	4057	3235	732	8736	0.56	0.55
TOTAL	4057	3235	732	8736	0.56	0.55



4 - SHOVEL AVAILABILITY AND UTILIZATION
HIGHVALE MINE: DART 600 C (No.8056)

Only one loader was available for the survey. The mechanical availability of 0.56 and equipment utilization 0.55 is much lower than of the shovels. In our case, the mechanical availability of loader is 31% lower and utilization is 21% lower than is average for the shovels. This is probably due to the frequent repair needed for the loader during the survey period, that increased down time considerably.

TIME STUDIES

During the spring and summer of 1983 when the field work was completed, a total of four shovels were working at the Highvale mine. Two of them, both BE-190B electric, were in Pit 02S (Nos. 1320 and 1353), another two, both BE-190B electric, in Pit 03 (Nos. 1337 and 1247). The Dart loader No. 8056 was studied for several days loading in Pit 03.

The loading of coal to the bottom-dump coal haulers was from three different elevations: with the loader below truck level, with the loader at the truck level, and with the loader dumping from above the truck level, stationed at the higher bench. The loading was done in two stages: (a) at first loading over front axle of the truck, (b) completion of loading over rear axle of the trailer (or truck box). The shovel operator used one short signal of the horn to indicate to the truck driver to move ahead for loading over the rear axle, two short signals to indicate completion of loading.

The shovels was loaded by swinging dipper from the side of the hauler, loading by Dart loader was directly by front dumping over the side of the truck.

The shovel was evaluated using field data and also historical data from the mine. The following assumptions were made:

A. Shovel movement was divided into two major groups:
   - operational
   - delays.

B. The operation at movement was divided into four subgroups:
   - Digging - above tub
   - below tub

- Swinging
- Dumping
- Return.

C. The delays monitored were categorized as:

- Walking
- Clean up
- Meal time
- Other.

Two shovel operations were monitored: No. 1247 in Pit 03 and No. 1320 in Pit 02S. Only on one occasion were trucks waiting for the shovel to move to a different location and the waiting time was 42 seconds. Other delays, such as meal times, were similar as for the trucks, delay and times were increased. The clean-up delay was not witnessed during the study. Other delays, mechanical problems, etc., amounted to total of 34 minutes 17 seconds for 12 hour shift for both shovels, or 2.4% of their total working time. Table 4 summarizes operation time for both shovels.

Table 4 - Shovel operation time summary (in sec)

Digging	Swinging	Dumping	Return
8.4	6.7	3.3	9.2

The digging was observed from above tub level only. Total time for each cycle averaged 27.6 seconds.

Assuming the theoretical capacity of a shovel bucket of 11.4 m^3, a total of 9 buckets is needed to fill both an Euclid 91T and a Cat 91T, 14 buckets to fill Terex 136T and 15 buckets to fill Kress 145T trucks. Table 5 summarizes the averages measured in field.

Table 5 - No. of buckets to fill trucks (coal only)

Truck	Theoretical no. of buckets		Field averages	
	Shovel	Loader	Shovel	Loader
Euclid 91T	9	7	8.6	-
Cat 91T	9	7	8.7	-
Terex 136T	14	11	13.8	10.7
Kress 145T	15	12	14.4	-

The Dart loader was observed loading Terex trucks for only six hours of operation. No delay times were measured.

By using values from Table 5, the total loading time for each truck has been calculated (Table 6).

Table 6 - Total loading time (shovel)

Truck	Total operating time (sec)	No. of cycles	Total loading time	
			(sec)	(min-sec)
Euclid 91T	27.6	8.6	237	3-57
Cat 91T	27.6	8.6	240	4-00
Terex 136T	17.6	13.8	381	6-21
Kress 145T	27.6	14.4	397	6-37

The mean average loading time for the Dart loader into the Terex truck was 7 min 43 sec. This number is based on summary of digging (12.3 sec), coal transportation (12.8 sec), dumping (4.1 sec) and return trip (14.1 sec), or a total of 43.3 sec. for one cycle. In summary, loading by Dart loader was about 21.5% slower than loading by the shovel (Terex trucks only monitored).

MODEL PARAMETERS

Several parameters were identified for the computer model to simulate the shovel/loader performance. The performance of shovels and loaders was directly related to the bucket capacity and to the total cycle time. The bucket capacity depends on size of the shovel, material handled and the bucket fill factor.

During the field studies at Highvale mine, only BE-190B shovels were monitored. These have bucket size of 11.48 m^3 (for coal loading). The material loaded by the shovels include both coal and the partings. The coal have bank weight of 1290 kg/m^3 and 40% swell factor, parting bank weight was estimated at 1360 kg/m^3 with about 40% swell factor.

The bucket fill factor was determined by dividing the truck load by the number of buckets and by comparing these values with the theoretical size of the bucket. Table 7 summarizes the calculation of the bucket fill factors for loader and shovel. The shovel dipper fill factor is 0.90 in average. The bucket fill factor for loader is 1.16. This figure could be non-representative, because the loader was monitored only once when loading Terex truck in Pit 03. The coal was quite fine and loader bucket was visually overfilled.

Table 7 - Bucket fill factors (coal loading)

Truck		No. of buckets to fill		Calculated capacity		Bucket fill	
Type	Capacity	Shovel	Loader	Shovel	Loader	Shovel	Loader
Euclid	81.8	8.6	-	90.8	-	0.90	-
Cat	81.8	8.7	-	91.9	-	0.89	-
Terex	130.9	13.8	10.7	145.7	113.0	0.90	1.16
Kress	138.3	14.4	-	152.1	-	0.91	-
AVERAGE						0.90	1.16

The cycle time for the shovel and loader were summarized in previous chapter, Table 4. It was concluded, that a total time for each cycle averaged 27.6 seconds for shovels and 43.3 seconds for the loader.

The total machine output was calculated by using the bucket capacity and the total cycle time, then reducing it for mechanical failure and waiting for the trucks time. The total production during any time interval "T" for any shovel can therefore be expressed as follows:

$$P = Q \quad \ldots\ldots\ldots\

material, the optimum depth of cut is equal to vertical distance from dipper stick pivot shaft to ground level.

Table 8 - Connection factors for depth of cut and angle of swing

Depth of cut in % of optimum	Angle of swing (degrees)						
	45	60	75	90	120	150	180
40	.93	.89	.85	.80	.72	.65	.59
60	1.10	1.03	.96	.91	.81	.73	.66
80	1.22	1.12	1.04	.98	.86	.77	.69
100	1.26	1.16	1.07	1.00	.88	.79	.71
120	1.20	1.11	1.03	.97	.86	.77	.70
140	1.12	1.04	.97	.91	.81	.73	.66
160	1.03	.96	.90	.85	.75	.67	.62

The wheel loader, when compared to shovel, is described similarly to the shovel for modelling purposes. In addition, the following specifications are defined (5):

A. Tire pressure. Recommended for optimum tire life and depends on the material loaded and type of ground the machine is expected to operate on.

B. Hydraulic cycle times:

a. Bucket lifting: Time in seconds required to raise the bucket from level position on the ground

b. Bucket lowering: Time in seconds required to lower the empty bucket from the full height to a level position on the ground.

c. Dumping: Time in seconds required to move the bucket from the load-carrying-position at maximum height to the full-dump-position while dumping an SAE operating load.

C. Breakout Force. The maximum sustained vertical upward force (in kN) exerted 102 mm behind the tip of the bucket cutting edge and fulfilling the following conditions:

a. Loader on a hard level surface with transmission in neutral.
b. All brakes released.
c. Unit at standard operating weight, rear of the loader not tied down.
d. Bottom of cutting edge parallel to and not more than 25 mm above or below the ground line.
e. When bucket circuit is used the pivot point must be specified as the bucket hinge pin.
f. When the lift circuit is used, the pivot point must be specified as the lift arm hinge pin.
g. If both circuits are used simultaneously, the dominating pivot point must be specified.
h. If the circuit used causes the rear of the vehicle to leave the ground then the vertical force value required to raise the rear of the vehicle is the breakout force.

Figure 15 illustrates used provisions to measure loader breakout force. The breakout force resulting from the rack-back is calculated as (5):

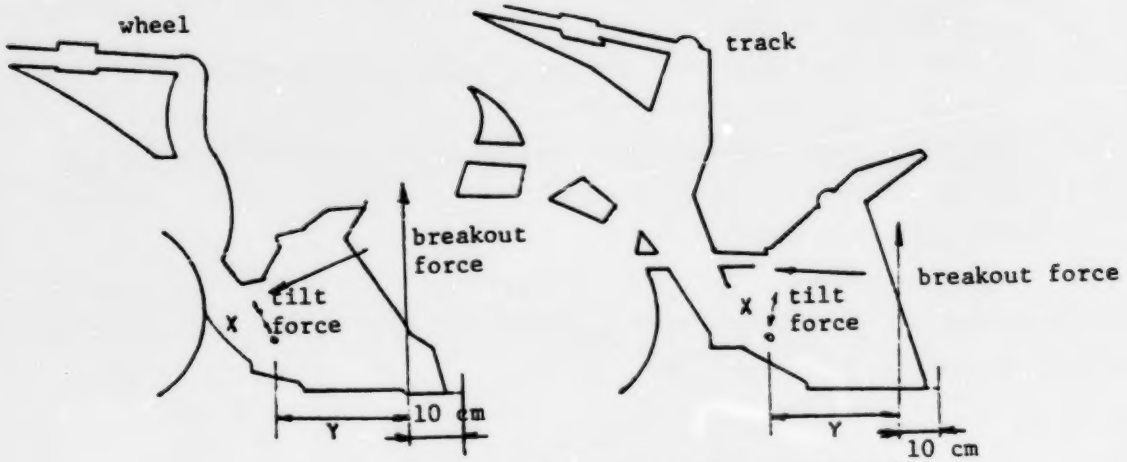
$$BF_{(RB)} = \text{Tilt Force x Distance "X"/Distance "Y"} \quad \ldots\ldots\ldots\ldots (8)$$

The breakout force resulting from bucket lift is calculated as (5):

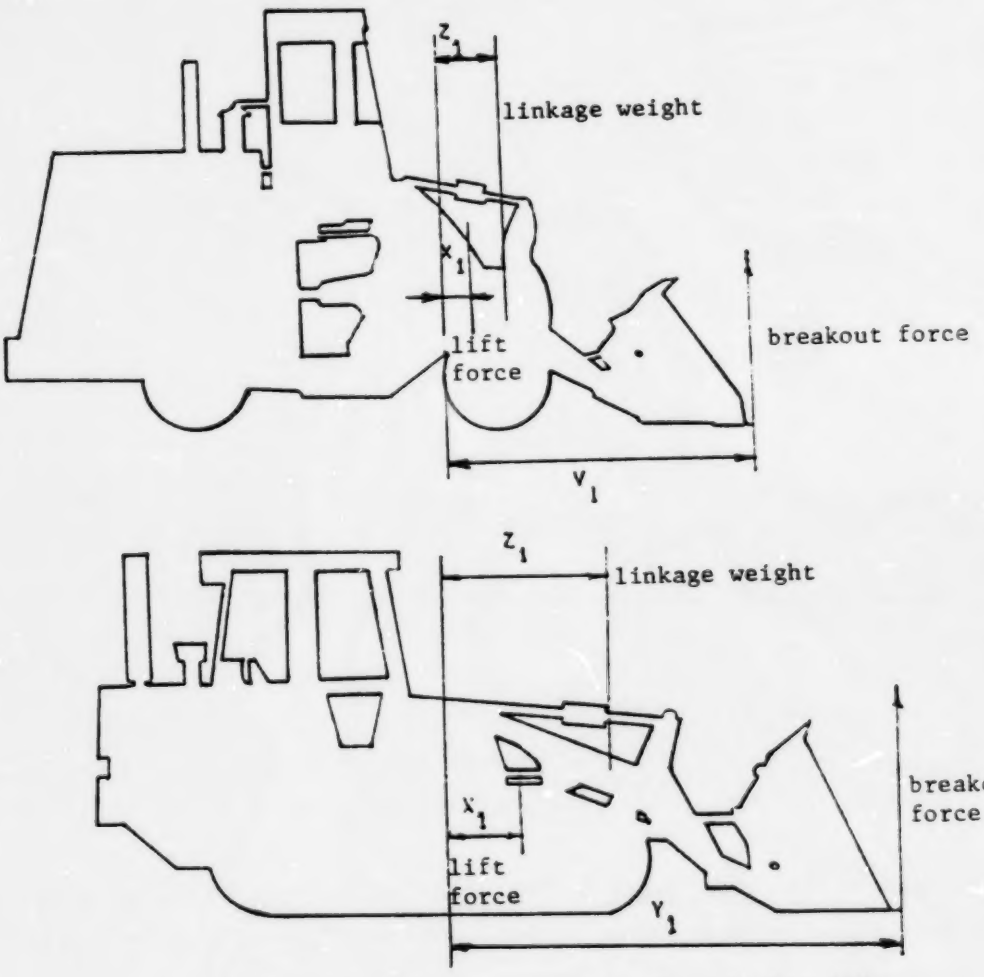
$$BF_{(BL)} = \frac{(\text{Lift force x dist. "X}_1\text{"}) - (\text{Linkage weight x dist. "Z}_1\text{"})}{(\text{Dist. "Y}_1\text{"}) + (\text{Dist. "V}_1\text{"}) \times (\text{Linkage mechanical advantage})} \quad \ldots\ldots\ldots (9)$$

D. Static tipping load. The minimum weight at centre of gravity of "SAE rated" load in bucket which will rotate rear of the machine to a point where front rollers are clear of the track (for track loaders) or rear wheels are clear of the ground (for wheel loaders). The following conditions apply:

a. Loader stationery on hard level surface
b. Unit at standard operating weight



a. Breakout force resulting from rack-back



b. Breakout force resulting from bucket lift

Fig. 15 - Breakout force of loader

c. Bucket tilted back

d. Load at maximum forward position during lifting cycle

e. Unit with standard equipment.

E. Operating load. The operating load of loaders should not exceed 50% of the full turn "static tipping" load of the machine when equipped with attachments needed for the job.

F. Carry position. The carry position is defined as "the vertical distance from the ground to the centre line of the bucket hinge pin, with the angle of approach at 15°" (5) (Fig. 16).

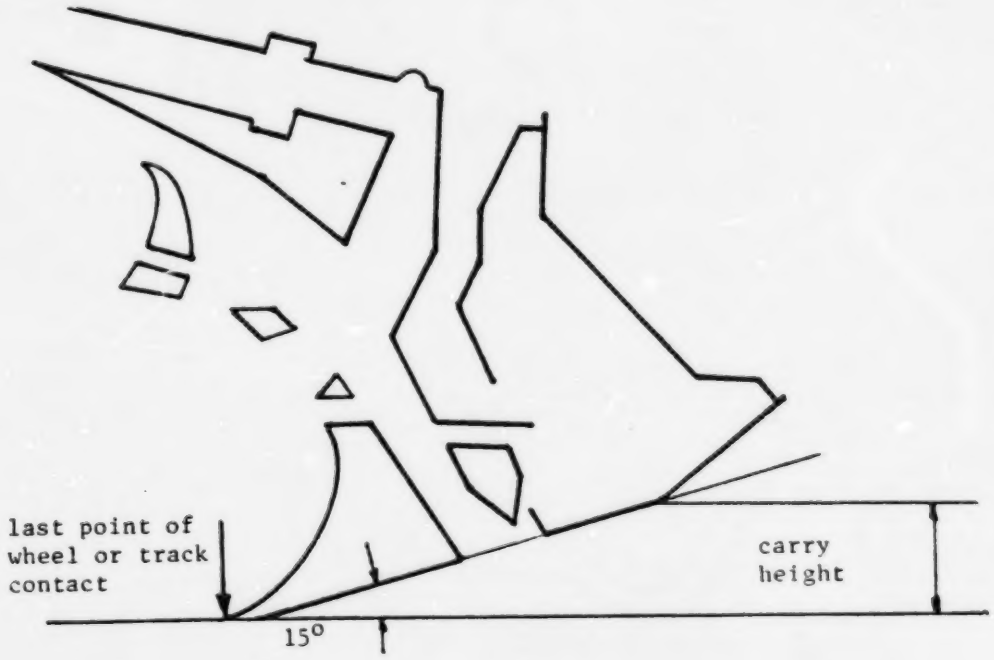


Fig. 16 - Carry position of loader

G. Loader clearance cycle. The loader clearance cycle is given in specification that also include minimum turning radius over the time.

H. Digging depth. The digging depth is in the vertical distance from the ground line to the bottom of the bucket cutting edge at the lowest position with the bucket cutting edge being horizontal.

I. Bucket capacities:

a. struck capacity - volume contained in a bucket after a load is levelled by drawing a straight edge resting on the cutting edge and the back of the bucket.

b. heaped capacity - struck capacity plus the additional material that would heap on the struck load at a 2:1 angle of repose with the struck line parallel to the ground.

The following is a list of parameters for shovel and loader model. Only BE-190B shovel specification and Dart 600C loader specification are included in this report, because only these two types are used at the Highvale mine. The general parameters shown in the enclosed Tables 9-12 and 15-18 are the parameters that will apply to any mine data base using the same shovel or loader. The power factors, moving time, operating time and digging rate factors are site specific and apply only to Highvale mine equipment (Fig. 13,14,20,21).

Table 9 - Parameters for shovel model - base

Truck frame - length	3303 mm
- width	3208 mm
Crawlers tread width	1422 mm
Effective bearing area	15.89 m^2
Ground pressure	209 kPa
Mounting - overall width	6250 mm
- overall length	6707 mm
Treads - No.	70
- pitch	413 mm
Rollers: lower - No.	8
- diameter	940 mm
upper - no.	4
- diameter	483 mm
Driving tumblers diameter	1026 mm
Take-up tumblers diameter	1069 mm
Propel drive speed	0.45 m/s
Gradeability - continuous	15%

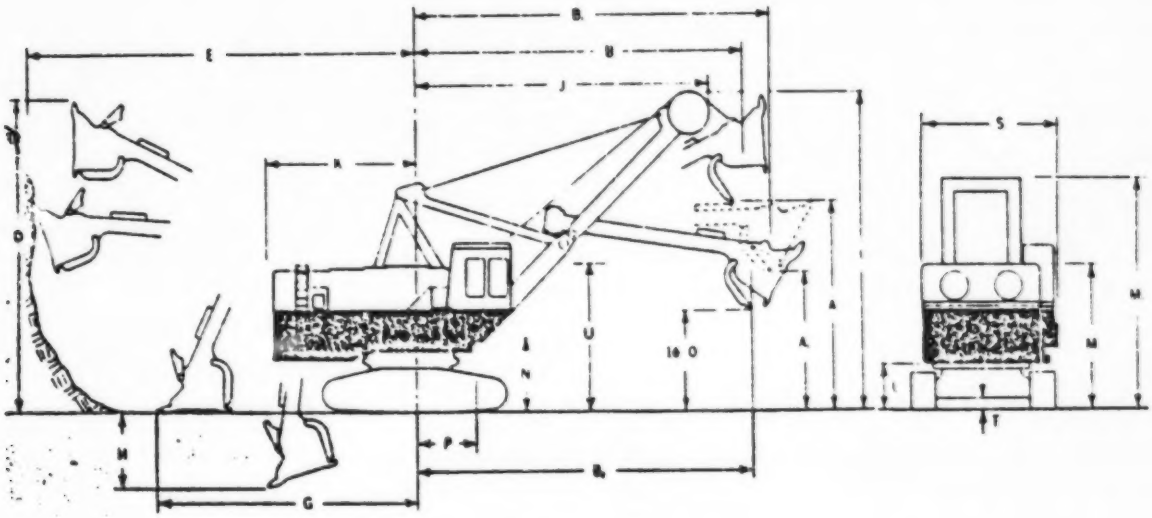
Table 10 - Parameters for shovel model - weights

Shovel Model: BE-190B	
Working weight	303 272 kg
Net weight	254 240 kg
Dipper	13 620 kg
Ballast	35 412 kg
Shipping weight - base	281 026 kg
- options	213 kg

Table 11 - Parameters for shovel model - general

Shovel Model BE-190B	
Boom- length	17 220 mm
- angle	50°
- point sheaves	1676 mm
Radius - dumping max.	17 835 mm
- dumping at max. height	16 845 mm
- cutting maximum	20 046 mm
- level floor	12 652 mm
- clearance boom point sheaves	14 939 mm
- clearance revolving frame	6021 mm
Height - dumping maximum	11 662 mm
- dumping at max. radius	7927 mm
- cutting maximum	16 082 mm
- clearance boom point sheaves	16 616 mm
- Top of "A" frame above ground	9502 mm
- Boom foot above ground level	3023 mm
Digging depth - below ground level max.	2592 mm
- below ground level	1982 mm
Boom foot to centre of rotation distance	2363 mm
Overall width of machinery house	6860 mm
Operator's eye level above ground	6555 mm
Standard bucket size - rock	6.70 m^3
- coal	11.48 m^3
Bucket (dipper) mass - coal	13 608 kg
Teeth no.	11
Handle diameter	610 mm
Handle length	9985 mm
Working mass with bucket - coal	339 740 kg
Net mass (without bucket and ballast)	270 794 kg
Ballast mass	55 338 kg
Shipping mass (with bucket without ballast)	283 949 kg

Table 12 - Parameters for shovel model - shovel working range



Dipper capacity (nominal)	6.88
Dipper capacities (range)	5-11
Length of boom	12.68
Effective length of dipper handle	7.77
Overall length of dipper handle	9.37
These dimensions will vary slightly depending upon dipper selection.	
Angle of boom	45°
A Dumping height - maximum	8.53 m
A_1 Dumping height at maximum radius-B_1	6.24
B Dumping radius at maximum height-A	13.87
B_1 Dumping radius - maximum	14.48
B_2 Dumping radius at 16'0" dumping height	14.32
D Cutting height - maximum	13.26
E Cutting radius - maximum	16.61
G Radius of level floor	10.74
H Digging depth below ground level - maximum	2.59
I Clearance height height - boom point sheaves	12.88
J Clearance radius - boom point sheaves	12.19
K Clearance radius - revolving frame	6.02
L Clearance under frame - to ground	1.88
M Clearance height top of house	5.74
M_1 Height of A-frame	9.50
N Height of boom foot above gound level	3.02
P Distance - boom foot to center of rotation	2.36
S Overall width of machinery house & operating cab	6.86
T Clearance under lowest point in truck frame	0.36
U Operator's eye level	5.49

Table 13 - Parameters for shovel model - power factors

Shovel Model BE-190B	
Digging	8.4 sec
Hoisting	6.7 sec
Dumping	3.3 sec
Return	9.2 sec
Manoeure time	25.0 sec
Swing empty	6.0 sec
Swing loaded	7.5 sec
Total cycle	27.6 sec
Spotting time	4.0 sec
Site clean-up	15.0 sec

Table 14 - Parameters for shovel model - operating time factors

Shovel Model BE-190B	
Shovel - availability	0.81
- utilization	0.70
Operator efficiency	0.90
Digging rate factor - blasted rock	1.00
- unblasted rock	1.25
Pit condition factor - excellent	
- good	0 bucket
- fair	-1 bucket
- poor	-2 bucket

Table 15 - Parameters for loader model - general

Operating mass	90 830 kg
Hinge pin maximum height	6579 mm
Bucket - width	5182 mm
- mass	7530 kg
- heaped (SAE)	15.3 m^3
Bucket roll back angle at ground level	50°
Bucket maximum dump angle at full height	50°
Maximum dump height at 45° dump angle	5410 mm
Reach when fully raised at 45° dump angle	2235 mm
Overall length-bucket on ground	13 894 mm
Machine width	5283 mm
Vehicle track	3480 mm
Clearance at maximum lift - dump @ 45°	4521 mm
- spillboard	6579 mm
- reach to ties @ 45°	2235 mm
Turning diameter (SAE) - outside bucket corner	21 235 mm
- outside front tire	18 339 mm
Static tipping load - straight ahead	51 973 kg
- full turn	45 714 kg
Breakout force	53 333 kg

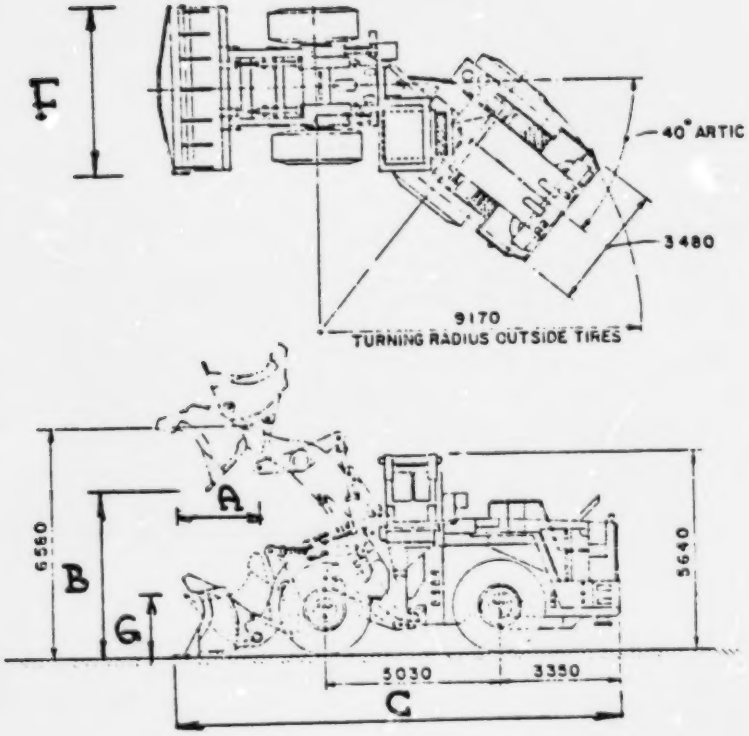
Table 16 - Parameters for loader model - engine

Make	Cummins
Model	KT 2300
Type	Diesel - 4 cycle
Aspiration	Turbo charged
Rated output (SAE) @ (1500) RPM	641 W
Maximum torque @ (1500) RPM	3181 N.m
Number of cylinders	12
Bore and stroke	159mm x 159mm
Piston displacement	37.69 L

Table 17 - Parameters for loader model - service data

Fuel tank	1589 litre
Hydraulic system (incl. tank)	802 litre
Axles (differential & planetary	1190 litre

Table 18 - Parameters for loader model - operating dimensions



Bucket size SAE heaped	11.47 m^3
Material weight	1780 kg/m^3
Bucket type	Mod. "V"
Dimensions	
A Reach	2.21 m
B Dump height	4.52 m
C Overal length (bucket down)	13.08 m
D SAE turning radius	10.24 m
E Overall width	5.00 m
F Nominal bucket width	4.72 m
G SAE rollback at ground (at carry)	50° (57°)

Table 19 - Parameters for loader model - operating data

Lifting and capacity at bucket hinge pin height	16 327 kg
- raise lift arms (loaded)	10.5 sec
- lower lift arms (empty)	5.3 sec
- dump bucket (loaded)	3.8 sec

Table 20 - Parameters for loader model - power factors

Loader Model Dart 600C	
Digging	12.3 sec
Moving	12.8 sec
Dumping	4.1 sec
Returning	14.1 sec
Manoeuvre time	40.0 sec
Swing empty	-
Swing loaded	-
Total cycle	43.3 sec
Spotting time	6.0 sec
Site clean-up	20.0 sec

Table 21 - Parameters for loader model - operating time factors

Loader Model Dart 600C	
Loader - availability	0.56
- utilization	0.55
Operator efficiency	0.85
Digging rate factor - blasted rock	1.00
- unblasted rock	1.15
Pit condition factor - excellent	+0.75 bucket
- good	0 bucket
- fair	-0.75 bucket
- poor	-1.5 bucket

CONCLUSION

The report summarizes the time study data and shovel/loader operating practices as observed at Highvale mine in Alberta during the period of June 1983 to February 1985. The shovel model BE-190B and loader model Dart 600C were studied in three pit operation.

The common practices and specific performances are listed in the chapters on shovel and loader performance.

The relationships between operating weight, horsepower, breakout force and bucket size are calculated and presented in graphs.

The production of shovel and loader, their availabilities and utilization data collected at Highvale mine are evaluated and graphs for each shovel and loader unit presented.

The shovel and loader operating times are summarized and tabled, delays and other non-productive times are listed. It was concluded, using field data, that average time for shovel cycle (digging-swinging-dumping-return) is 27.6 seconds, average time for loader cycle (digging-transport-dumping-return) is 43.3 seconds. The BE-190B shovels were observed loading onto four types of truck (Euclid 91T, Cat 91T, Terex 136T, Kress 145T), Dart 600C loader into the Terex 136T truck only. The loading times, numbers of bucket to fill the trucks are summarized in Tables 5 and 6. In the last chapter, parameters of shovels and loader are listed in the same way that will be entered into the equipment data base. The bucket fill factors, correction factors for depth of cut and angle of swing and equations used to calculate the of machine output and subsequently in develop the mathematical model of shovel and loader operation are presented.

The data and description of operating practices of shovels and loaders will be used in development and validation of truck/shovel computer model presently under the study by the National Research Council in Ottawa and Calgary Coal Research Laboratory in Calgary.

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APPENDIX A: LISTING OF DATA ON FILE

	NUMBER DOWN TIME	MONTH DELAY TIME	OP.HRS.COAL IDLE TIME	OP.HRS.PART TOTAL HOURS	OP.HRS.TOT.
1	1	APR.1982	326	75	401
	49	62	208	720	
2	2	MAY 1982	357	91	448
	61	79	156	744	
3	3	JUNE 1982	220	45	265
	241	48	166	720	
4	4	JULY 1982	250	57	307
	131	103	203	744	
5	5	AUGUST 1982	33	0	33
	456	31	224	744	
6	6	SEPT.1982	255	217	472
	37	76	135	720	
7	7	OCT.1982	234	234	548
	37	85	74	744	
8	8	NOV.1982	381	61	466
	67	91	24	648	
9	9	DEC.1982	589	12	621
	61	86	48	816	
10	10	JAN.1983	395	94	489
	43	188	24	744	
11	11	FEB.1983	285	114	400
	194	54	24	672	
12	12	MAR.1983	331	212	543
	111	90	0	744	
13	13	APR.1983	539	34	573
	43	80	24	720	

LISTING COMPLETED

	NUMBER DOWN TIME	MONTH DELAY TIME	OP.HRS.COAL IDLE TIME	OP.HRS.PART TOTAL HOURS	OP.HRS.TOT.
1	1	APRIL 1982	321	133	454
	33	57	176	720	
2	2	MAY 1982	199	41	240
	323	51	130	744	
3	3	JUNE 1982	331	147	478
	47	63	132	720	
4	4	JULY 1982	207	70	277
	246	60	161	744	
5	5	AUG.1982	335	231	566
	29	85	64	744	
6	6	SEPT.1982	300	136	436
	60	66	157	720	
7	7	OCT.1982	272	198	483
	24	69	168	744	
8	8	NOV.1982	276	163	449
	49	126	24	648	
9	9	DEC.1982	345	275	655
	39	74	48	816	
10	10	JAN.1983	480	79	559
	33	128	24	744	
11	11	FEBR.1983	377	46	423
	145	80	24	672	
12	12	MAR.1983	304	261	565
	97	82	0	744	
13	13	APR.1983	306	248	554
	46	96	24	720	

LISTING COMPLETED

	NUMBER DOWN TIME	MONTH DELAY TIME	OP.HRS.COAL IDLE TIME	OP.HRS.PART TOTAL HOURS	OP.HRS.TOT.
1	1	APR.1982	276	175	451
	27	64	178	720	
2	2	MAY 1982	288	217	505
	63	76	100	744	
3	3	JUNE 1982	224	311	535
	65	60	60	720	
4	4	JULY 1982	110	68	178
	334	35	197	744	
5	5	AUG.1982	247	79	326
	174	51	193	744	
6	6	SEPT.1982	162	226	388
	121	58	154	720	
7	7	OCT.1982	339	99	444
	21	73	206	744	
8	8	NOV.1982	355	154	519
	24	81	24	648	
9	9	DEC.1982	426	183	650
	32	86	48	816	
10	10	JAN.1983	319	211	530
	16	174	24	744	
11	11	FEB.1983	224	221	445
	128	75	24	672	
12	12	MAR.1983	379	208	587
	75	82	0	744	
13	13	APR.1983	374	91	465
	143	88	24	720	

LISTING COMPLETED

	NUMBER DOWN TIME	MONTH DELAY TIME	OP.HRS.COAL IDLE TIME	OP.HRS.PART TOTAL HOURS	OP.HRS.TOT.
1	1	APRIL 1982	347	127	474
	21	63	162	720	
2	2	MAY 1982	267	115	382
	110	59	193	744	
3	3	JUNE 1982	235	19	254
	291	30	145	720	
4	4	JULY 1982	216	83	299
	214	69	162	744	
5	5	AUGUST 1982	295	31	326
	176	47	195	744	
6	6	SEPT.1982	331	102	434
	48	56	182	720	
7	7	OCT.1982	288	56	356
	92	64	232	744	
8	8	NOV.1982	436	55	520
	27	77	24	648	
9	9	DEC.1982	530	40	583
	115	70	48	816	
10	10	JAN.1983	168	154	322
	18	380	24	744	
11	11	FEBR.1983	186	231	417
	138	93	24	672	
12	12	MARCH 1983	354	49	403
	266	75	0	744	
13	13	APRIL 1983	0	0	0
	0	0	720	720	

LISTING COMPLETED

	NUMBER DOWN TIME	MONTH DELAY TIME	OP.HRS.COAL IDLE TIME	OP.HRS.PART TOTAL HOURS	OP.HRS.TOT.
1	1	APRIL 1982			
	680		40	720	
2	2	MAY 1982	101	125	226
	201	59	217	744	
3	3	JUNE 1982	170	100	270
	246	43	156	720	
4	4	JULY 1982	192	166	358
	129	56	163	744	
5	5	AUGUST 1982	283	49	334
	163	49	198	744	
6	6	SEPT.1982	234	72	306
	144	48	200	720	
7	7	OCT.1982	215	81	310
	158	44	232	744	
8	8	NOV.1982	133	130	275
	318	31	24	648	
9	9	DEC.1982	237	138	400
	329	39	48	816	
10	10	JAN.1983	299	180	479
	101	140	24	744	
11	11	FEB.1983	303	175	478
	107	63	24	672	
12	12	MAR.1983	140	198	338
	312	94		744	
13	13	APR.1983	99	184	283
	347	66	24	720	

LISTING COMPLETED